Hands-on Research Excites High School Students

A unique experiment in educational outreach is underway in the School of Engineering, as part of a research program funded by the National Science Foundation (NSF) under its Information Technologies Research (ITR) initiative. The experiment involves bringing two top junior or senior students from nearby E.O. Smith High School, Mansfield, into an intensive summer research program in which they collaborate on an interdisciplinary research project. Mechanical Engineering professor Ranga Pitchumani is the principal investigator on the team, with colleagues Luke Achenie, associate professor of Chemical Engineering and Eugene Santos, associate professor of Computer Science & Engineering.

The project began in 2002 when NSF awarded the interdisciplinary team more than $400,000 to support its proposed three-year project, entitled "Simulation and Optimization of Thermal Manufacturing of Materials Under Uncertainty: Application to Optical Fiber Drawing."

Superintendent of Schools (district 19) Bruce Silva supported the partnership between E.O. Smith and the research team, and during the summers of 2002 and 2003, two students were selected each year to participate on the project. "I am excited that some of our top students have the opportunity to benefit from this unique educational experience—to actually work in a research lab and contribute toward something concrete," says Mr. Silva. "It's a great way to expose them to careers and educational avenues to which they may not otherwise gain exposure. This is a terrific demonstration of the power of education."

The students spend one summer working hands-on with the project team. Each receives a stipend and is expected to contribute toward the lab research, attend meetings and present findings both orally and in report form. The subject of the research project is optical fibers, which carry light as a means of transporting information, energy and other data from one place to another. They are found in diverse applications in telecommunications, computers, manufacturing and the media. But to function well in the applications, the optical fibers must be of extremely high purity, strength and refractivity.

For this reason, Dr. Pitchumani observes, manufacture of optical fibers is a complex operation that involves multi-physics phenomena which need to be well understood and carefully controlled. The process begins with production of the original glass "preform blank" under controlled conditions, during which a precise mixture of chemicals with suitable additives—called dopants—are heated in oxygen to extremely high temperatures. Next, the glass preform is loaded onto a tower structure and placed in a furnace, where it is heated to the point it becomes molten. The molten glass gradually descends into a thin thread and is pulled to achieve the desired diameter of about 125 microns necessary for an optical fiber. The fiber passes through an acrylate (polymer) coating die and the coated fibers are wound up in reels.

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The process is very dynamic and, moreover, several material and operational parameters of the process are uncertain, leading to variability in the fiber quality. A careful design and control of the chemical composition and heating conditions are necessary to achieve the desired optical properties of the fiber, in a reliable and repeatable manner.

Dr. Pitchumani explains that the multidisciplinary research team, which includes engineering faculty, graduate students and E.O. Smith students, has several objectives: (1) to develop a physics-based process model for optimal manufacture of optical fibers, (2) to systematically account for the parameter uncertainty in the simulations so as to predict the product quality variability, and (3) to resolve the significant computational challenges arising from the large scale stochastic simulation of the manufacturing process.

In attempting to resolve the computational challenges, says Dr. Santos, two main issues must be addressed: how to equitably distribute the computational effort across a heterogeneous network of heterogeneous machines; and how to anticipate, analyze the difficulty of, and quickly answer questions as they arise. "Our solution," he says, "is to employ a flexible mobile multi-agent approach where the agents represent such questions and can migrate from computer to computer and have an adaptive model that allows the system to 'learn from experience' how hard certain questions might be."

The team will produce a comprehensive simulation tool and an efficient computational framework for analysis and design of the process under uncertainty. The development and testing of such a complex system requires a great deal of data collection, visualization, and analyses. This is an area where the E.O. Smith interns have played key roles in advancing the team's work while providing them with hands-on research experience.

Dr. Achenie, whose expertise lies in process design and computation, is involved in helping the team achieve its second objective: to account for the parametric uncertainties in the model so it accurately predicts the variation in product quality. Many parameters are present in the manufacture of optical fibers, explains Dr. Achenie, and there is a broad range of variability for each parameter. The simulation of the process has to be done for all possible values of the parameters while taking into account the fact that within a parameter's range of possible values, some are more likely than others. To carry out the simulations on one computer takes a considerable amount of

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time. The distributed computing approach exploits the fact that some of the computing tasks can be done simultaneously on several computers, thus drastically reducing the overall simulation time. One of the summer 2003 E.O. Smith students who collaborated on the project, Catherine Thorkelson (now studying at Columbia University), helped Dr. Achenie by converting the model's programmatic code, originally written in Fortran, to the more efficient C++.

The third objective of the team, to resolve the computational challenges inherent in this complex model, is being addressed by Dr. Santos, who is developing the framework for multiple networked computers to tackle the problem concurrently rather than serially. At the end of the three-year funded project the team aims to have developed a comprehensive process model implemented on an agent-based distributed computational framework comprising a network of PCs, Apple X servers, and Unix workstations for rapid simulation, analysis, and optimization of the process.

One of the two 2002 student participants, Liang Pei, now an undergraduate student in the School of Engineering, gave the internship top marks. "I felt the experience was up to my expectations. I helped solve problems by collecting and analyzing data—and this was all for achieving a goal, not just problems on a test or homework. It was a totally new experience…I enjoyed the feeling of working on and accomplishing something that actually has meaning," he says. Liang's work involved testing different algorithmic methods of running large-scale calculations on the distributed computing environment to save time. Based on this information, he drew conclusions about which algorithms were the most efficient. In addition to helping in the lab, he participated actively in weekly/biweekly meetings, made research presentations to the group and created the first project web site.

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